AFCESA

TECH DATA BULLETIN

PROPANE-AIR
MIXING PLANTS
FEBRUARY 1997

PROPANE-AIR MIXING PLANTS

SYNOPSIS

This tech data bulletin provides an overview of a propane-air mixing plant's operation, its major components, and a method of evaluating the feasibility of a propane-air mixture plant installation at any Air Force base.

INTRODUCTION

Propane-air systems offer an alternative to underground storage tanks and a solution to high natural gas costs. A propane-air mixing system allows an installation to switch from higher firm service gas rates to lower cost interruptible rates. The propane plant is an insurance policy that is turned on during those few days when your natural gas supplies are interrupted. These systems have been acquired through the Energy Conservation Investment Program and Energy Savings Performance Contracts.

WHY PROPANE-AIR MIXING PLANTS

Most natural gas utilities offer both firm and interruptible gas service. Firm service is purchased for requirements such as base housing which do not have backup fuel. Interruptible service is usually purchased for a heat plant where fuel oil is available for periods of gas interruptions. Generally, the firm price per decatherm or Mcf-used is considerably higher and may include a demand charge. Through the use of interruptible fuel an installation may realize savings in both the cost of the gas and the demand charge. However there must be alternative fuel available to continue during interruption of gas delivered. A propane storage plant can be used as an alternative fuel to convert either part or all of a load to interruptible service when there is no fuel oil backup. Due to the structure of natural gas pricing and higher cost associated with larger propane-air mixing facilities, it may be economically advantageous to maintain some firm natural gas supply and convert only part of the load to the interruptible rate schedule. In this case, propane is used for the load peak that exceeds the firm gas availability when interruptible gas is not available, hence the term "peak shaving." Interruptible gas is normally used whenever available because it is less expensive than propane.

CODE REQUIREMENTS

Space Criteria

When considering the installation of a propane-air plant, space requirements are important. NFPA 58 and OSHA are the basic codes that are generally followed. Local codes vary widely and should be consulted.

Distance Criteria

Storage tanks over 2,000 gallons must be located at least 50 feet from buildings or property lines that can be built upon. Vaporizers must be placed 10 feet from unloading facilities, 15 feet from tanks, and 25 feet from buildings. These distances may be modified by local governing authorities. Some insurance companies require up to 75 feet between tanks, vaporizers, and unloading facilities. Figures 1, 2, and 3 show the respective propane-air mixing plant installation requirements: NFPA, Factory Mutual, and Industrial Risk Insurers.

Fire Protection

Additional fire protection may also be required, particularly in built-up areas. This may take the form of insulation, deluge water systems, or putting the storage tanks underground. The appropriate local and state authority and insurance companies should be contacted for the particular requirements.

Environmental Considerations

Environmental permitting is not generally required for a propane-air mixing plant. The storage tanks do not generally require permitting or registration. There are no Environmental Protection Agency (EPA) requirements for leak detection or monitoring systems. The vapor pressure of propane is such that any propane that is released to the atmosphere will vaporize immediately. Propane is heavier than air and precautions should be taken to ensure that the propane-air mixing plant is not located in a depression or surrounded by dikes or berms. Propane is not an ozone depleting substance. State and local permitting requirements should be investigated prior to proceeding with a project.

Noise

The propane-air mixing plant will generate noise from air compressors. Special consideration should be given to noise reduction.

Propane-Air Mixture Characteristics

When vaporized and properly mixed with air, propane gas can be used in existing systems fired with natural gas. Propane-air mixture cannot be used to fuel natural gas vehicles. Air must be mixed with the propane because the density and heating value of propane is much higher than that of methane, the primary component of natural gas. The approximate ratio of dilution of the propane required is 45.1% air and 54.9% propane. The resulting mixture has a specific gravity of about 1.287 and a BTU value of approximately 1400 BTU/CF, which is compatible with natural gas-fired equipment.

The Wobbe Index is the best indicator of the similarity between a specific natural gas and propane-air mixture. The Wobbe Index is a number indicating the interchangeability of fuel gases. It relates fuel gas heating characteristics in a manner that is useful for blending fuel gases, or to obtain a constant heat flow from a gas of varying composition. The Wobbe Index does not relate to such technical factors as flame temperature, heat transfer coefficients or temperature gradients. It is obtained by dividing the heating value of the gas by the square root of its specific gravity. If the natural gas and propane-air mixture have an identical Wobbe Index, they will produce an equivalent amount of heat and combustion products and will require the same amount of combustion air. Burners provided with a replacement of a lower Wobbe Index will experience minor combustion changes. Substitution of a gas for one with a higher Wobbe Index generally allows a narrow acceptance range. Flame characteristics determine the acceptance range for a propane-air mixture.

The Wobbe Index generally groups the heating characteristics of fuel gases in a more usable format than classification by calorific value due to composition variations. The Wobbe Index varies over a much narrower range, providing a more realistic value by which to control the heat flow.

PROPANE-AIR MIXING PROCESS

There are five separate steps in the propane-air mixing plant process. (See Figure 4.) The steps are:

1. Liquid propane (LP) gas unloading,
2. Storage of liquid propane gas,
3. Liquid transmission from storage to the vaporizer,
4. Propane vaporization, and
5. Propane-air mixing process.

Design for LP-gas plants is basically the same, regardless of ultimate use, and certain items of equipment are required in all cases. Major equipment items include the storage system, unloading facilities, propane pumps, vaporizer, and mixing equipment.

For proper selection of equipment the following information is required:

- Maximum hourly demand;
- Heating value;
- System pressures;
- Space requirements.
- Availability of railroad siding or trucking facilities for the transport of the propane to the site.
- How often propane can be supplied to the site.

Unloading Facilities

Provisions for propane deliveries to the site must be made when designing a propane-air mixing plant. Only two methods of delivery are available, by truck or by rail. If a rail line is in place and readily accessible, its use should be considered, especially for larger plants. However, most propane-air mixture plants rely on truck transports for delivery of propane. Accessibility, roadway support, and safety considerations must be taken into account when designing the unloading facility.

The unloading parking apron for a transport truck must be level to allow for maximum propane transfer. If the apron is not level it will limit the amount of fuel that can be off-loaded from the transport truck. Truck delivery of propane can be accomplished using bobtail or transport truck. The bobtail truck is the normal delivery method to small customers, particularly residential customers. Bobtail trucks range in size from 2,000 to 3,500 gallons of capacity. It is the most costly method of propane delivery. If the unloading apron is not level, delivery will only be possible by bobtail truck. Transport trucks typically range in capacity from 9,000 to 11,600 gallons and either unload from the center or rear end of the trailer.

The propane truck is equipped with a liquid pump. The liquid pump is used to push the liquefied propane gas from the truck's tank to the propane-air mixture plant's storage tanks. The transfer of the propane is accomplished by connecting two hoses to the unloading station (See Figure 5). One hose is attached to the vapor line connection, which is piped to the vapor connection of the storage tanks. The second hose is attached to the liquid line connection, which is piped to the liquid connection of the storage tanks. The liquid is located on the propane truck. After the hoses have been connected to the unloading station the LP-gas is pumped into the storage tanks and the vapor in the storage tank is evacuated into the truck's tank. When all of the liquid is removed from the truck's tank the unloading process is complete. The vapor remaining in the truck's tank cannot be recovered using a liquid pump.

The method of unloading a rail car is different than the method for unloading a truck. The propane plant must have a railroad unloading tower and a rail car unloading compressor. Unlike trucks, rail cars are not equipped with pumps or compressors for unloading. The suction end of the compressor is piped to the vapor connection of the storage tanks. The rail car vapor hose is connected to the discharge of the compressor. The unloading of the rail cars is accomplished by the compressor drawing vapor form the storage tanks, compressing the vapor to a higher pressure and sending the compressed vapor to the rail car. The compressed vapor displaces the liquid in the rail car tank. The liquid in the rail car tank is forced into the liquid hose and into the storage tanks. When all of the liquid has been removed from the rail car tank, the compressor is reversed so that the suction end of the compressor is connected to the rail car and the discharge is connected to the unloading station’s liquid line connection. The rail car's liquid outlet valve is then closed, and the compressor is used to transfer the vapor from the rail car to the storage tanks. The vapor is sent through the liquid inlet of the storage tanks causing the vapor to condense as it enters the tank. The majority of the vapor in the rail car can be removed.

Storage System

Propane is stored under pressure in liquid form. The size of the pressure vessels vary from small cylinders, used on fork lift trucks, up to 90,000 gallon storage tanks. The storage tanks must be manufactured in compliance with the applicable Codes of the American Society of Mechanical Engineers (ASME). The tanks will have an ASME stamp if they are manufactured in accordance with the Codes. The usual size range for commercial standby plants is from 1,000 up to 30,000 gallons. The latter size is the most widely used as it permits truck transport delivery at a lower cost from the supplier, with 50% capacity in the storage tank.

The actual size of the storage facility depends upon the demand of the process and the availability of a propane supply. A standby system should have a minimum of one week of storage.

For example: An Air Force base has a process operating 10 hours per day, at an average usage of 18 million BTU/hr. The propane required will be 1980 gallons per day. A 30,000 gallon storage tank will provide a 14-day supply. (*A 30,000 gallon storage tank can only be filled to 88% capacity at 60°F.*) See Chart 1.

The storage tanks will require the following accessories:

1. Fill port or fill opening valve
2. Liquid outlet port or process opening valve
3. Vapor area opening valve
4. Pressure gauge
5. Liquid level gauge
6. Thermometer
7. Pressure relief valves
8. Excess flow valves
9. Back pressure check valves
10. Rotometer

(See Figure 6).

Storage tanks can be installed underground. Underground tanks will have additional requirements consisting of the following:

1. Man-way hatch
2. Cathodic protection
3. Tar coating
4. Concrete ballast

Propane Pumps

The propane must be delivered under pressure to the mixing station. In most instances, the vapor pressure of the propane in the storage tanks is adequate to deliver the propane to the mixing station at sufficient pressure. However, the vapor pressure in the tank is dependent upon the volume and temperature of the propane (See Chart 2). As the propane temperature drops and/or the tank empties the vapor pressure in the tank may not be adequate to deliver the propane to the mixing station at sufficient pressure. During these conditions liquid propane pumps are used to provide sufficient propane flow and pressure at the mixing station. Propane pumps are either of the positive displacement or turbine type.

Vaporizers

In some small applications, vaporization can take place in the storage tank and vapor can be taken directly from the tank. The rate of vaporization is a direct function of the heat transfer through the tank wall to the liquid. A 30,000 gallon storage tank will vaporize only 4.5 million BTU/hr of liquid in a tank half full on a 0°F day, at 5 psig. The smaller the tank, the less vaporization will take place; an 1850 gallon tank will vaporize 650,000 BTU/hr at the same conditions.

In most standby systems, a vaporizer is utilized to convert liquid propane to gaseous propane, since vaporization produces a chilling effect and heat must be added to stabilize the process. The vaporizer may be *steam-fired, direct gas-fired, direct-fired water-bath,* or *electrically heated*. The choice depends on the availability of steam or electricity, physical space limitations, demand requirements, and the quality required of the air-gas mix. The *direct fired water-bath* vaporizer is the most likely choice for a plant of sufficient capacity to serve an Air Force installation.

The *steam-fired* unit utilizes a steam coil to vaporize the propane. This unit is relatively small in size and can be installed adjacent to the plant. The capacities range up to 400 million BTU/hr.

Direct-fired vaporizer uses a burner to heat a chamber containing propane similar to a pot of boiling water on a kitchen range. These units have a maximum capacity of approximately 7 million BTU/hr and are manifolded where greater capacities are required. There is a large variation in propane vapor temperature from a direct-fired unit. This will vary the specific gravity of the propane, which will vary the BTU content of the propane-air mix. These vaporizers must be located at least 25 to 75 feet from a building or storage tank.

Direct-fired water-bath vaporizers use a burner system to heat a solution of ethylene-glycol, which indirectly heats a coil containing the propane (See Figure 7). The output temperature of the vapor is more consistent than direct-fired systems. The water bath models range in size from 7 million BTU/hr to 900 million BTU/hr in one unit. The location requirements are similar to that of a direct-fired unit, 25 to 75 feet from a building or storage tank.

Electrically heated vaporizers are generally small in size and capacity, under 3 million BTU/hr. They are used where limited space is available or in areas which may be hazardous. They are built to Class I, Group D electrical specifications (explosion-proof), and can be located next to buildings.

Mixing Stations

Propane-air mixing plants can be categorized into three types; Venturi, Blower-Mixer, and High Pressure Mixing (See Figure 8).

Venturi Type Propane under pressure is delivered through a venturi nozzle and air is inspirited through the venturi and mixed with the propane. The resultant mix is generally delivered to a surge tank, as the limited turndown of the venturi requires it to be operated on an off/on cycle. The process load operates from the surge tank and the venturi operates to maintain the tank pressure. The number of venturis, their individual capacity, and the size of the surge tank will establish the maximum capacity available from the system. The range of sizes goes from 0-4 million BTU/hr with one venturi, up to 200 million BTU/hr with eight or more venturis, with output pressure from 6 to 10 pounds per square inch gage (psig), depending on a particular manufacturer.

Blower-Mixer Type A blower-mixer type draws air and propane into the inlet of the fan, mixes it, and delivers it to the system at an increased pressure of 6 inches water column (wc) to 2 psig. The turndown of this type system is generally eight to one.

High Pressure Mixing Type In this system, propane is delivered to a mixing chamber under pressure. The air is delivered to the same mixing chamber from a high pressure blower or air compressor. The mix is then fed to the piping system. The propane is usually pumped to the vaporizer to provide the necessary pressure for the operation. Output pressure can range to 150 psig. This is the most common type of system at larger installations like an Air Force base, due to the higher delivery pressure usually required by the bases. Figure 9 shows a schematic diagram of a propane-air mixing plant which utilizes this type of mixing.

FEASIBILITY ANALYSIS

The feasibility analysis for a propane-air mixing plant involves quantifying the potential savings and the cost to construct and operate the plant. Savings result from the lower cost of interruptible gas and the avoidance of demand charges. A demand charge is usually associated with the firm gas only and can be based either on a contractually specified maximum daily quantity or of a maximum usage established during a set time A demand charge is usually assessed on a monthly basis and provides the utility with funds to make service available If the cost of natural gas includes a separate component for transportation charges, calculations must account for the difference in interruptible and firm transportation rates. Several cases should be considered with different levels of firm and interruptible service with appropriately sized propane-air mixing plants in order to determine the point of optimum savings. Savings are determined by comparing the existing total cost of natural gas service, including any demand or transportation charges, to the total rate determined by comparing the cost of natural gas purchased under the existing service agreement and rates, and the cost of the same quantity of gas purchased under an interruptible rate. See Appendix B.

POINT OF CONTACT

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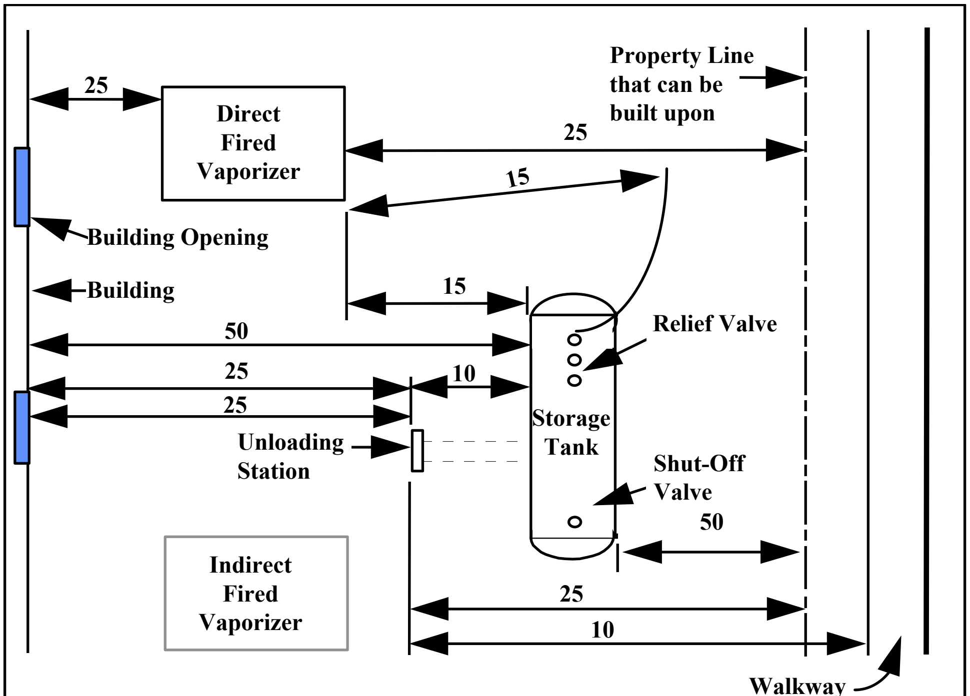

Figure 1: NFPA Code Requirements

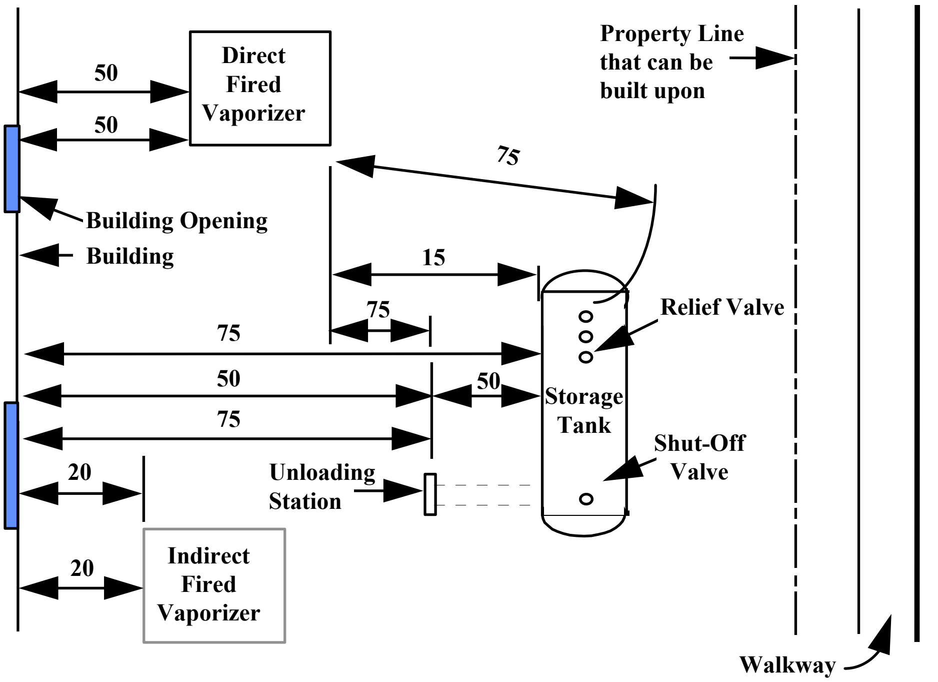

Figure 2: FM Code Requirements

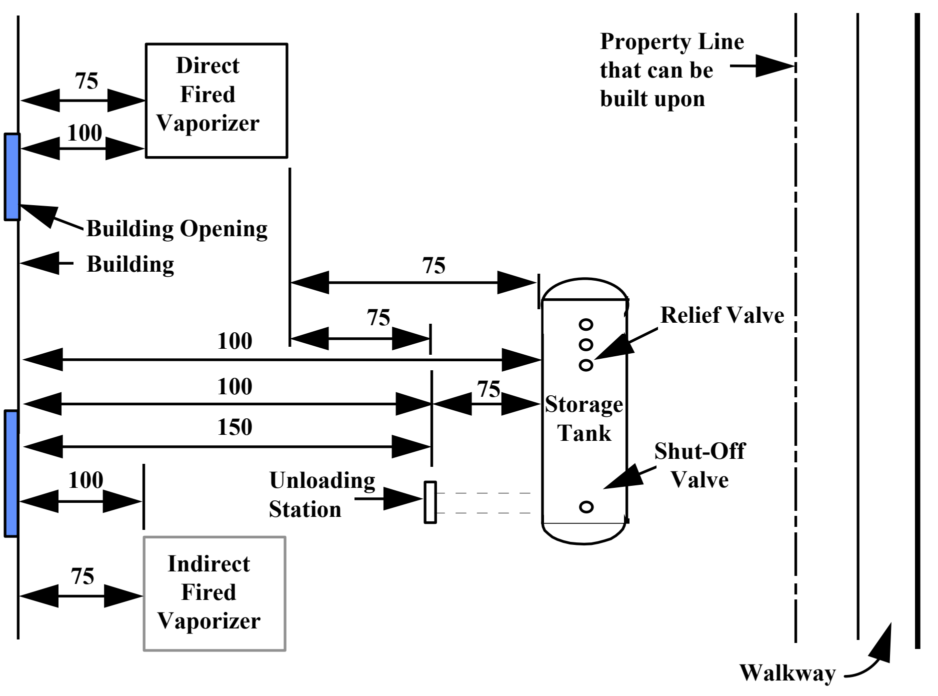

Figure 3: IRI Code Requirements

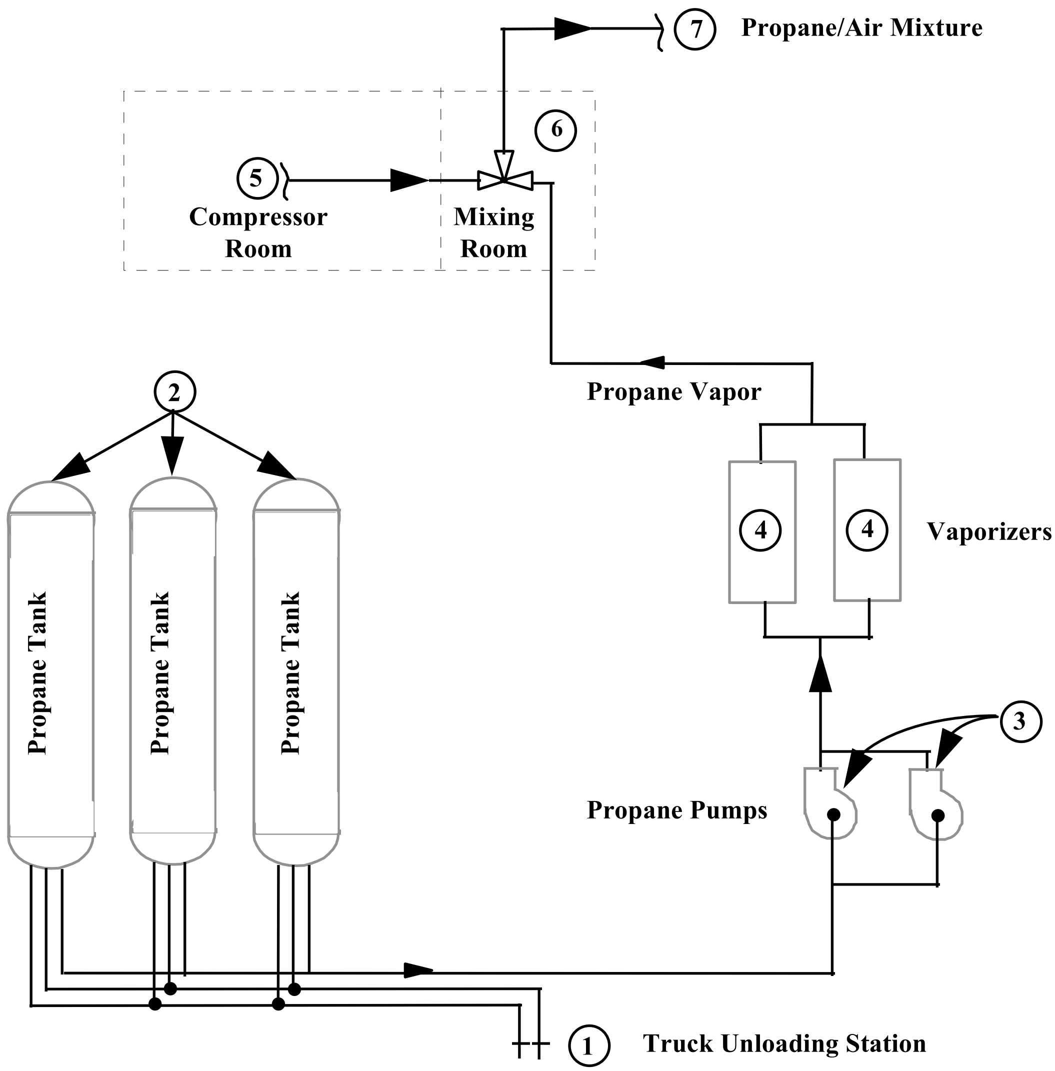

Figure 4: Propane Plant Process

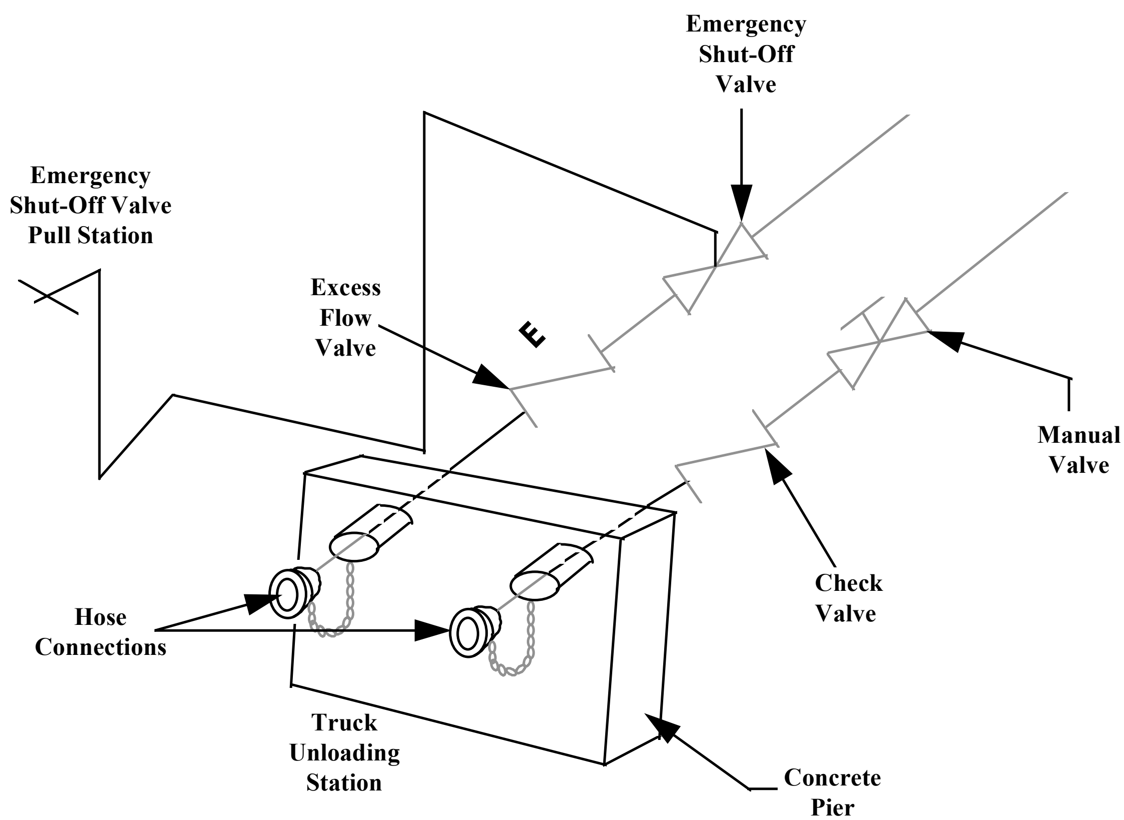

Figure 5: Truck Loading Station

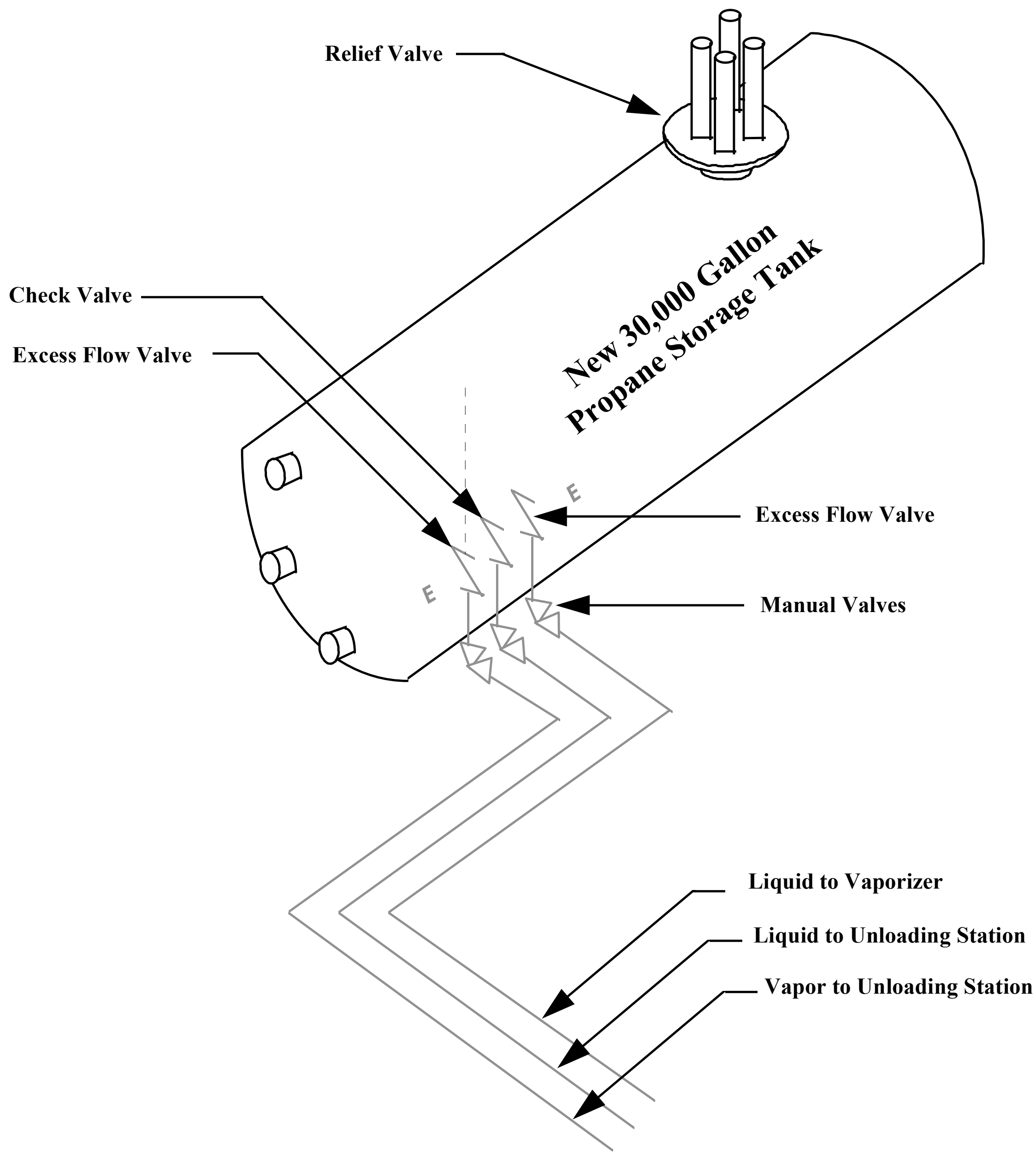

Figure 6: Propane Tank

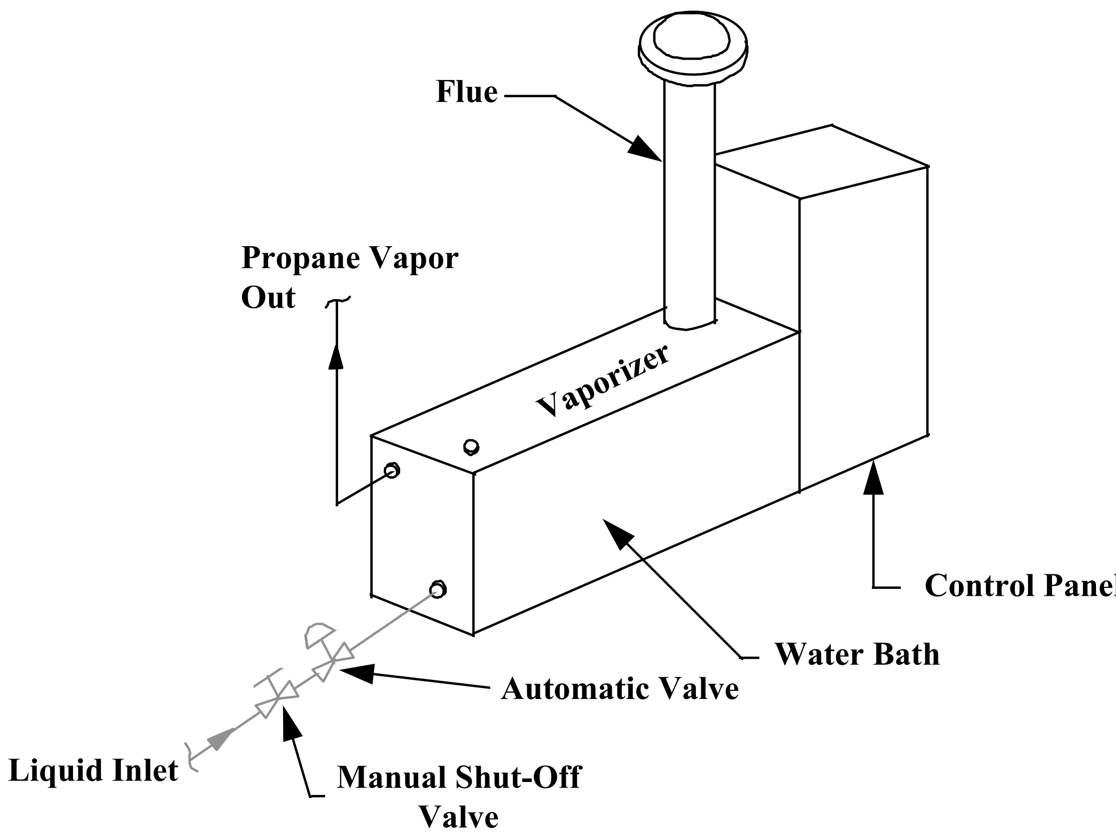

Figure 7: Vaporizer

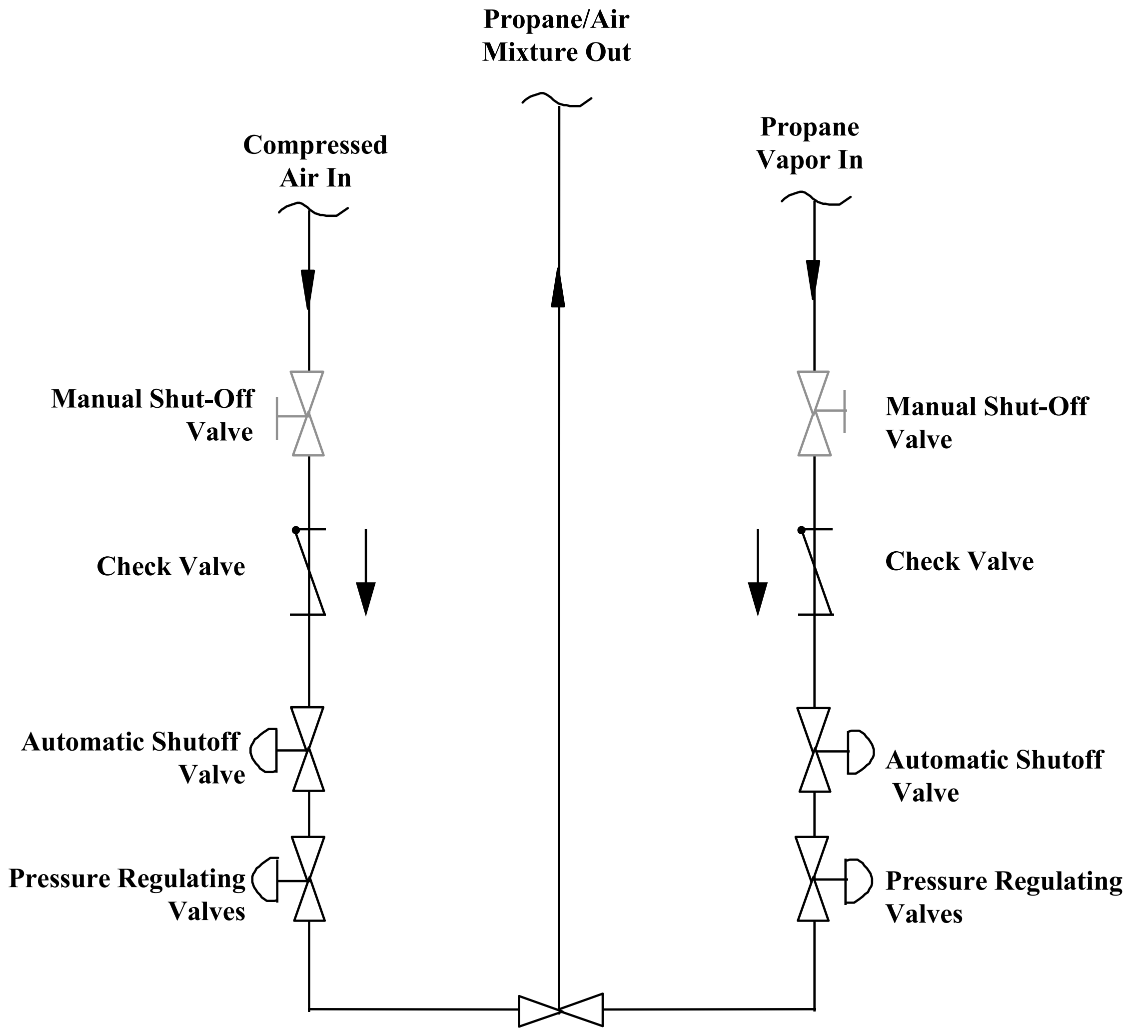

Figure 8: Propane-Air Mixing Station

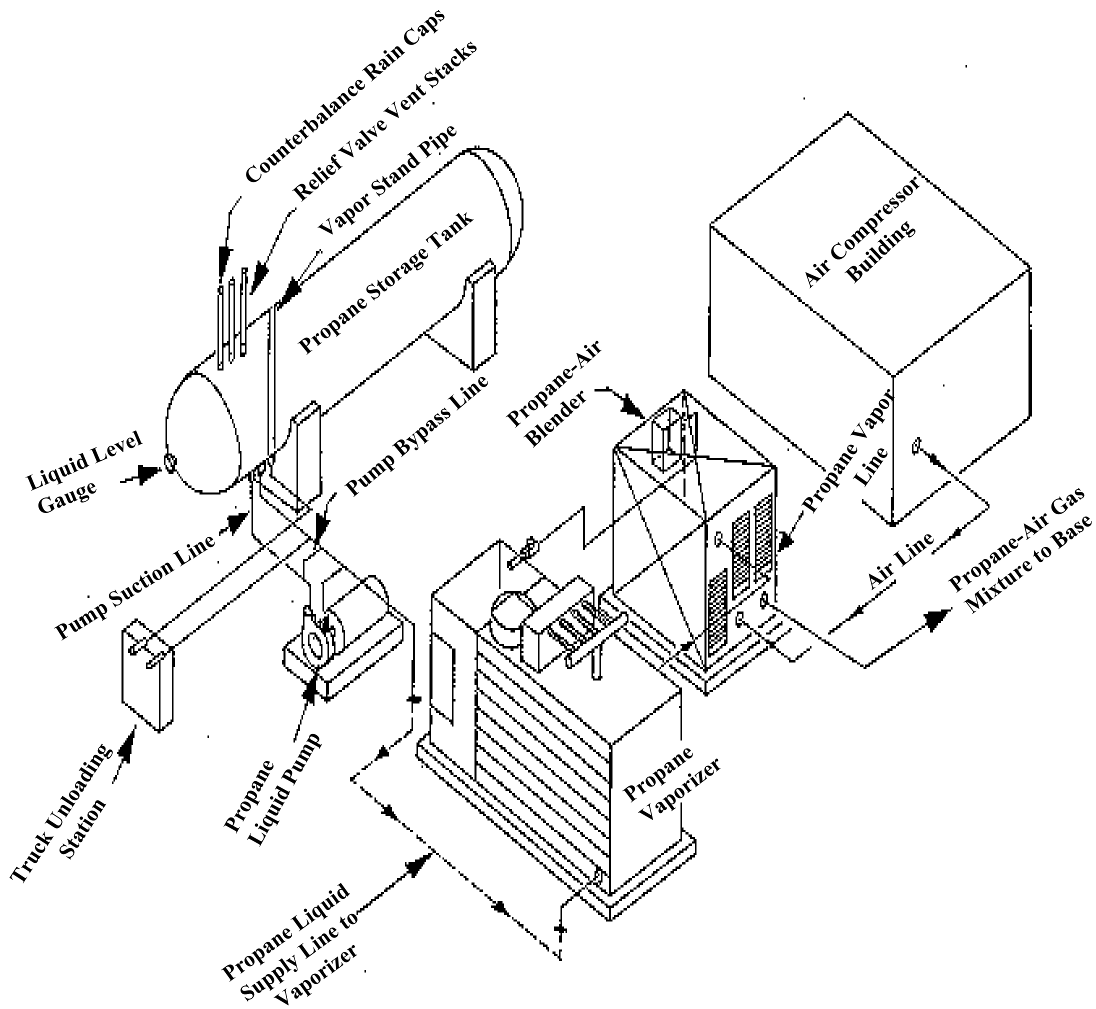

Figure 9: Propane-Air Plant

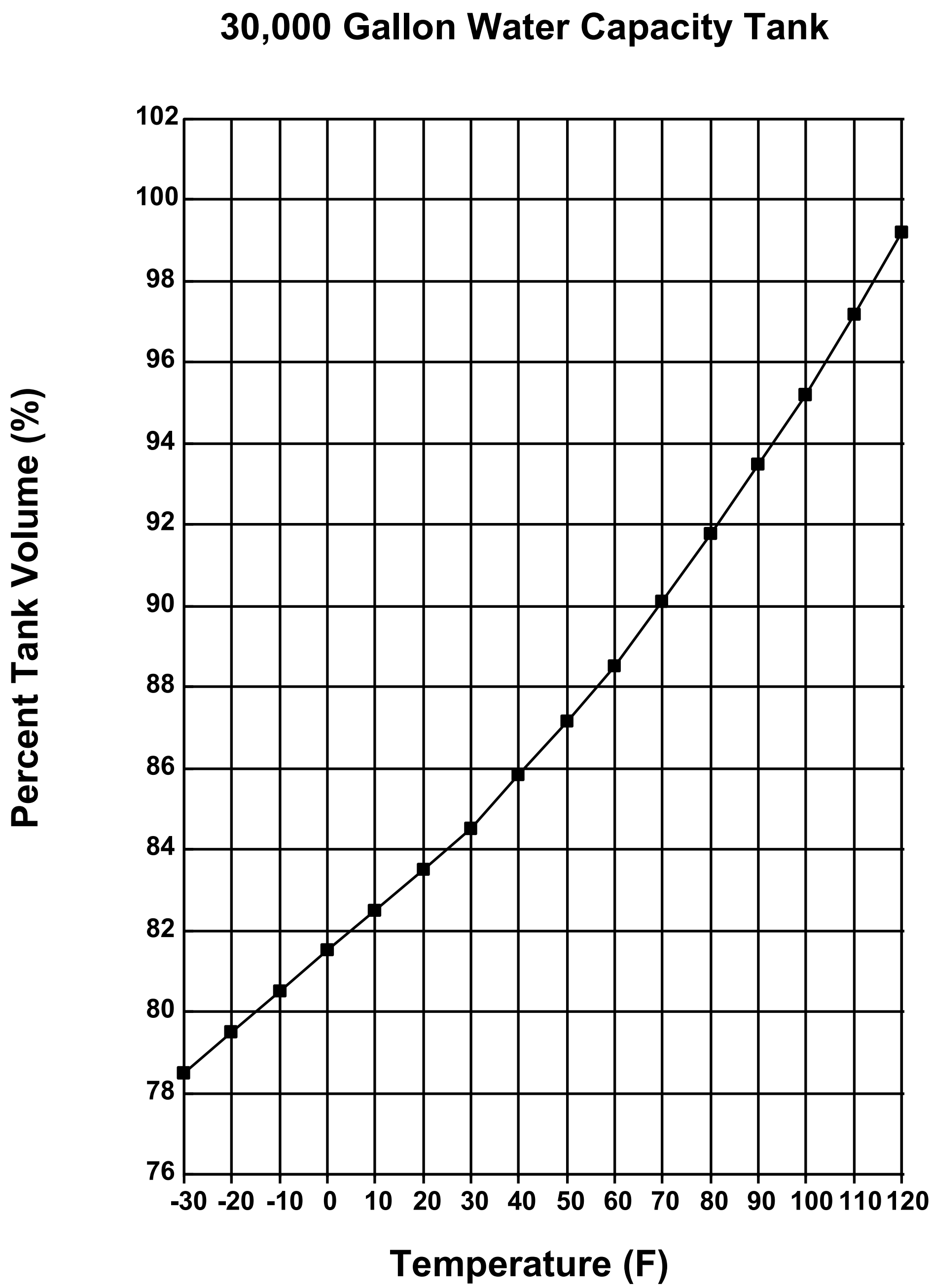

Chart 1: Tank Filling Capacity

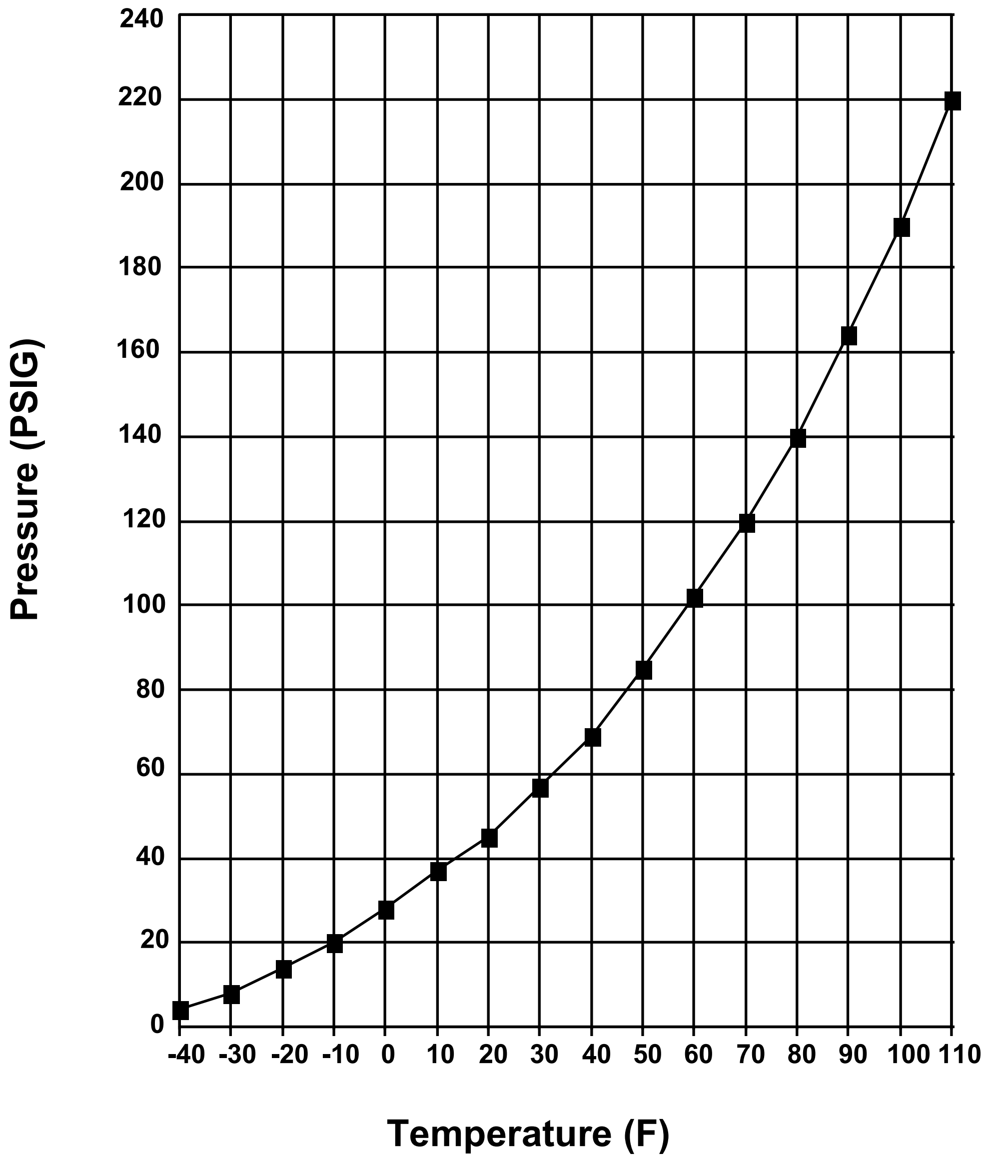

Chart 2: Vapor Pressure Of Propane

SAVINGS DETERMINATION
STEALTH AFB

HISTORICAL GAS CONSUMPTION (THERMS)

Aug-92	*Sep-92*	*Oct-92*	*Nov-92*	*Dec-92*	*Jan-92*	
27831	26862	83814	262115	456334	387124	
Feb-93	*Mar-93*	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	
385982	358223	140324	39040	24802	28172	
						Total
						2220623

BASELINE NATURAL GAS COST

Stealth AFB-contracted daily availability 8000 therms

	Aug-92	*Sep-92*	*Oct-92*	*Nov-92*	*Dec-92*	*Jan-93*	
Daily Availability	$10,400.00	$10,400.00	$10,400.00	$10,400.00	$10,400.00	$10,400.00	
Cost of Gas	$10,854.09	$10,476.18	$32,687.46	$102,224.85	$177,970.26	$150,978.36	
Transportation	$2,031.66	$1,960.93	$6,118.42	$7,300.00	$7,300.00	$7,300.00	
Transportation Over 100	$0.00	$0.00	$0.00	$9,726.90	$21,380.04	$17,227.44	
Franchise Recovery	$298.62	$293.31	$605.38	$1,582.38	$2,646.60	$2,267.37	
TOTALS	$23,584.37	$23,130.42	$49,811.26	$131,234.13	$219,696.90	$188,173.17	
	Feb-93	*Mar-93*	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	Total
Daily Availability	$10,400.00	$10,400.00	$10,400.00	$10,400.00	$10,400.00	$10,400.00	$124,800.00
Cost of Gas	$150,532.98	$139,706.97	$54,726.36	$15,225.60	$9,672.78	$10,987.08	$866,042.97
Transportation	$7,300.00	$7,300.00	$7,300.00	$2,849.92	$1,810.55	$2,056.56	$60,628.04
Transportation Over 100	$17,158.92	$15,493.38	$2,419.44	$0.00	$0.00	$0.00	$83,406.12
Franchise Recovery	$2,261.11	$2,109.00	$915.03	$360.04	$282.02	$300.49	$13,921.35
TOTALS	$187,653.01	$175,009.35	$75,760.83	$28,835.56	$22,165.35	$23,744.13	$1,148,798.48

INTERRUPTIBLE NATURAL GAS COST

Stealth AFB-interruptible

	Aug-92	*Sep-92*	*Oct-92*	*Nov-92*	*Dec-92*	*Jan-93*	
Daily Availability	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Cost of Gas	$6,679.44	$6,446.88	$20,115.36	$62,907.60	$109,520.16	$92,909.76	
Transportation	$1,669.86	$1,611.72	$5,028.84	$15,726.90	$27,380.04	$23,227.44	
TOTALS	$8,349.30	$8,058.60	$25,144.20	$78,634.50	$136,900.20	$116,137.20	
	Feb-93	*Mar-93*	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	Total
Daily Availability	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Cost of Gas	$92,635.68	$85,973.52	$33,677.76	$9,369.60	$5,952.48	$6,761.28	$532,949.52
Transportation	$23,158.92	$21,493.38	$8,419.44	$2,342.40	$1,488.12	$1,690.32	$133,237.38
TOTALS	$115,794.60	$107,466.90	$42,097.20	$11,712.00	$7,440.60	$8,451.60	$666,186.90

TOTAL PROJECT SAVINGS $482,611.58

APPENDIX A

NATURAL GAS						
Unit of Measure	BTU	Pound	Therm	Decitherm	Ft^3	Gallon
Ft^3	1040		0.011	0.11	1	

PROPANE-AIR MIXTURES				
BTU/FT^3 ($KCAL/NM^3$)	% Propane by Volume	% Air by Volume	% Oxygen by Volume	Specific Gravity of Mixtures
1700 (15130)	66.67	33.33	6.694	1.349
1650 (14685)	64.7	35.3	7.378	1.338
1600 (14220)	62.74	37.26	7.787	1.328
1500 (13350)	58.82	41.18	8.606	1.308
1450 (12950)	56.86	43.14	9.016	1.297
1400 (12450)	54.9	45.1	9.246	1.287
1350 (12015)	52.94	47.06	9.835	1.277
1300 (11580)	50.98	49.02	10.245	1.267
1250 (11125)	49.02	50.98	10.654	1.357

APPENDIX B

PHYSICAL PROPERTIES OF PROPANE	
Formula	C_3H_8
Molecular Weight	44.097
Melting (or Freezing) Point, ^oF	-305.84
Boiling Point, ^oF	-44
Specific Gravity of Gas (Air = 1.00)	1.52
Specific Gravity of Liquid 60^{o}F/60^{o}F (Water = 1.00)	0.588
Latent Heat of Vaporization at Normal Boiling Point BTU/lb.	183
Vapor Pressure, lb./in.^{2} Gauge at 60^{o}F	92
Lbs. per Gallon of Liquid at 60^{o}F	4.24
Gallons per lb. of Liquid at 60^{o}F	0.237
BTU per lb. of Gas (gross)	21591
BTU per ft^3 Gas at 60^{o}F and 30" Mercury	2516
BTU per gal. of Gas at 60^{o}F	91547
Ft^3 of Gas (60^{o}F, 30" Hg)/Gallon of Liquid	36.39
Ft^3 of Gas (60^{o}F, 30" Hg)/Lb. of Liquid	8.58
Ft^3 of Air Required to Burn 1 ft^3 Gas	23.87
Flame Temperature, ^oF	3595
Octane Number (Iso-Octane = 100)	125

CONSTANT MEASUREMENTS				
Unit of Measure	BTU	KWH	Therm	Decitherm
BTU	1	0.000293	0.00001	0.0001
KWH	3413	1	0.00341	0.0341
Therm	100000	29.3	1	10
Decitherm	10000	2.93	0.1	1

PROPANE EQUIVALENTS						
Unit of Measure	BTU	Pound	Therm	Decitherm	Ft^3	Gallon
Pound	21591	1	0.216	2.16	8.58	0.239
Therm	100000	4.622	1	10	39.7	1.1
Decitherm	10000	0.4622	0.1	1	3.9	0.11
Ft^3	2516	0.1164	0.025	0.25	1	0.027
Gallon	91547	4.24	0.916	9.16	36.39	1

APPENDIX B